DOCUMENT RESUME

ED 150 831 EC 104 200

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TITLE Oscillographic and Physiological Measurements of Delayed Auditory Feedback and Anxiety Factors in Stutterers and Non-Stutterers.
INSTITUTION Spencer Foundation, Chicago, Ill.
PUB DATE 77
NOTE 58p.

EDRS PRICE MF-$0.83 HC-$3.50 Plus Postage.
DESCRIPTORS Articulation (Speech); Exceptional Child Research; *Feedback; *Performance Factors; Speech Handicapped; Speech Therapy; *Stuttering

ABSTRACT

Reported are five studies on the use of delayed auditory feedback (DAF) with stutterers. The first study indicates that sex differences and age differences in temporal reaction were found when subjects (5-, 7-, 9-, 11-, and 13-years-old) recited a nursery rhyme under DAF and NAF (normal auditory feedback) conditions. The second study is reported to have found significant overall discrepancies in the binaural conduction of sound for stutterers and non-stutterers. It is explained that the third study indicated no difference in anxiety level between stutterers and non-stutterers under NAF and DAF conditons, while a fourth study confirmed that finding. The fifth study cites the finding that stutterers were found to differ significantly from non-stutterers in disfluency counts, with no evidence that stuttering was decreased through the use of DAF. Implications for speech therapy are noted. (CL)

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Oscillographic and Physiological Measurement of Delayed Auditory Feedback and Anxiety Factors in Stutterers and Non-Stutterers[1]

A Report Prepared for The Spencer Foundation, 1977

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OSCILLOGRAPHIC AND PHYSIOLOGICAL MEASUREMENT OF DELAYED AUDITORY FEEDBACK AND ANXIETY FACTORS IN STUTTERERS AND NON-STUTTERERS[1]

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The purposes of the research were: (1) to refine the measurement of reaction to delayed auditory feedback (DAF) and the measurement of stuttering behavior through the use of a modified oscillograph which was capable of production of sound spectrograms (voice prints), (2) to compare in detail the reactions of stutterers and non-stutterers under DAF and normal auditory feedback (NAF) conditions, (3) to measure internal and external passage of sound from larynx to mastoid process in stutterers and non-stutterers, (4) to investigate the possibility that stutterers experience DAF as a function of physiological conduction rates, indicating that stuttering and reaction to DAF are the same phenomenon, (5) to explore the anxiety component described in the literature on stuttering and DAF reaction.

Fluent speech involves the use of auditory, kinesthetic and proprioceptive, feedback. Auditory feedback normally occurs through both air and bone-tissue-air conduction. There is a slight discrepancy in time between air and bone-tissue-air conduction, as demonstrated by Stromsta (1962). Delaying air-conducted sound through the use of a modified tape recorder and headphones increases the discrepancy between air-conduction and bone-tissue-air conduction as well as between air-conduction and production of sound. This

artificial delay (DAF) often results in disruption of speech which has been labelled "artificial stutter" (Lee, 1950).

The most obvious effect of DAF upon speech is a marked slowing. This has been noted by a number of investigators, including Lee (1950), Black (1951), Spilka (1954), Tiffany and Hanley (1956), and Chase, Harvey, Standfast, Rapin, and Sutton (1958, 1959). Measurement of the slowing of speech by DAF has been accomplished in several ways.

Black (1951) used a measure of duration of speech which was length of passage divided by time taken to read the passage (words per second). Difference scores obtained from rate of reading under DAF conditions and no delay conditions were used by Hanley and Tiffany (1954). Spilka (1954) found percentage phonation time useful.

When Fairbanks (1955) measured rate of reading of 16 male subjects at delays of .0, .1, .2, .4, and .8 seconds on a 98 word passage, he found a marked slowing at .1, .2, and .4 seconds. Delay time of .8 seconds showed only a slight slowing; while .2 seconds was the delay time with maximum slowing of reading rate. He stated that the results were a function of increased speech errors and actual slowing of speech. Correct word rate was used as a measure of reaction. The correct words were expressed as relative values with rates for the no delay condition equaling one.

With the use of a cathode-ray oscilloscope and photography as measuring devices; Chase, Harvey, Standfast, Rapin and Sutton (1958, 1959) asked 14 subjects to repeat the sound "b" under conditions of no delay and .24 seconds DAF. This method allowed for direct

measurement and conversion to time values. They found that there was an increase in duration in intersyllable intervals with DAF.

Korobow (1955) used time to respond in a free-response situation as a measure of reaction to DAF. He found no differences at .18, .27, and .36 seconds DAF.

The approaches to measurement of reaction to DAF vary greatly, but there is agreement on the usefulness of a time measure. The most accurate measure takes into account the verbal performance of subjects under conditions of no delay as well as under DAF. Otherwise, no baseline from which to measure DAF reaction alone is provided. The slower the rate of verbalization under DAF in comparison to the rate under no delay, the greater the reaction is reported to be.

Another common measure of speech reaction to DAF is increase in speech disfluencies. Atkinson (1954), using a delay range of .03 to .27 seconds, studied the effect of DAF on intelligibility of speech as measured by frequency of speech errors (disfluencies). He reported that the manner in which delay time affected intelligibility was not linear; and from his data was not predictable. No pattern of effects of different delay times on intelligibility was noted. Chase, Sutton, Rapin, Standfast, and Harvey (1959) found similar results.

Gains in disfluencies (omissions, substitutions, additions, and miscellaneous errors) in relation to delay times of .0, .1, .2, .4, and .8 seconds were studied by Fairbanks and Guttman (1958). They found articulation errors to be at a maximum at .2 seconds delay which lends support to Fairbanks'(1955) contention that maximum

slowing of rate at .2 seconds is due to increased errors as well as actual slowing of speech.

Several theorists have attempted to relate reaction to DAF and stuttering (Lee, 1950; Fairbanks, 1954; Black, 1955; Chase, 1958; Yates, 1963; and Tomatis, 1963). Their theories and comparisons have been mainly concerned with neurological disturbances which have been said to comprise the basis of both DAF reaction and stuttering. Some have also noted anxiety as a part of both phenomena.

Finding similarities and differences between DAF and stuttering seems quite useful, if only in helping to promote understanding of stuttering. There are other considerations also. Experimenters are now using DAF in therapy with stutterers with much success. In these cases, DAF is used as a tool in shaping of a new speech pattern with quite long lasting positive results (Ryan, 1974). More experimentation is necessary before this form of therapy can become widespread.

Support for the hypothesis that DAF reaction has a physiological basis equivalent to, if not the same as, that which is presented for stutterers above, can be found in the research on age and sex differences in reaction to DAF, twins' reactions under DAF conditions, and from analyses of spectrograms. Chase, Sutton, First, and Zubin (1961) noted that young children seemed less affected by DAF than did older children. Subjects between the ages of 4 and 6 years were affected less in rate change from NAF to DAF as measured by words per second than those children in the age range of 7 to 9 years. During the NAF, the younger children were slower and prolonged more words than did the older children. However, differences

in rate between DAF and NAF conditions were significantly greater for the older group than for the younger group. Percentages of words repeated, syllables repeated, and intrusions did not differ significantly for the two groups.

MacKay (1968) and Buxton (1969) reported that younger children show more reaction to DAF than do older children, but that delay times to which children show maximum reaction differ by age group. MacKay (1968) demonstrated that subjects aged 4 to 6 years showed maximum reaction to DAF at .524 sec. delay, using frequency of repetitions as a measure of reaction. Seven to 9 year olds reacted most to a delay time of .375 sec., while an adult group reacted maximally to .2 sec. DAF. Buxton (1969) found that subjects aged 4 to 9 years reacted most strongly to .6 sec. DAF, while those aged 10 to 26 years reacted with maximum disruption to .2 sec. DAF, and those 60 to 81 years of age were affected most by a delay time of .4 sec.

It is thought that although there is some evidence of a developmental trend in reaction to DAF, the age groupings and differences in measurement used may mask some existent differences. If differences in reactions can be specifically demonstrated, control of age as a factor in future experimentation with DAF will be necessary. Knowledge of developmental aspects of DAF reaction may also be useful in therapy with stuttering children.

Berry and Eisenson (1956) reported that girls begin to speak earlier than do boys. They also arrive at articulatory proficiency earlier and have better language control than do boys, during at

least the first ten years of life. McCarthy (1954) and Tyler (1965) reported definite sex differences favoring girls in all aspects of language development through the preschool and primary grades. According to Schuell (1946) the speech defective population included a proportionately higher number of males than females in all age groups and for most defects of speech. Morley (1952) agreed that among university students with speech defects there was one female to every 1.5 to 3.4 males. McCarthy (1954) indicated that girls' utterances were more comprehensible at an early age than those of boys. These differences were said to decrease with age. On the average, however, girls continued to excel boys in linguistic functions.

King and Dodge (1965) mentioned the fact that their male adult subjects spoke more slowly under both no delay and DAF conditions than did female subjects. Mahaffey and Stromsta (1965) investigated this variable more thoroughly. They found a significant interaction among filter conditions, sex, delay, and intensity weightings. The mean duration measure for females was significantly larger under loudness balanced filtered conditions than under nonloudness balanced filtered conditions of DAF for delay times of .0, .09, .18, and .27 sec. DAF for females, and at .18 sec. DAF for males. When the feedback was made more intense by loudness balancing, increased duration of speech was noted at no delay and all delay times used. Loudness balancing had the greatest effect on males when frequencies above 2400 cps were attenuated. Females were affected more when frequencies below 600 cps were attenuated. Mahaffey and Stromsta (1965) suggested that on the basis of their findings there may have

been inherent differences in the relationship between hearing and speech for males and females.

Timmons (1971) reported that when using delay times of .0, .1, .2, .3, .4 and .5 sec. randomly presented in a repeated measures design with adult subjects, no differences were found between reactions of males and females. When DAF conditions were compared on the basis of the order of their presentation, sex differences at the .05 level of confidence were noted. The ordered means for females were in nearly perfect descending order, while the means for males remained quite constant. The sex differences reported were attributed to a hypothesized adaptation to DAF by females. This was related to Stromsta's (1956) hypothesis that stuttering resulted from DAF; and that the ability to adapt to DAF may be an important factor in the production of fluent speech.

Twins' reactions to DAF were studied by Timmons and Rankin (1970). Identical and fraternal twin pairs were tested under .0 and .2 sec. DAF. Time differences were used as a measure of DAF reaction. Both a Pearson product-moment and Kendall's tau correlational method were used in comparison of twin siblings. Identical twin pairs correlated .85 Pearson and .67 Kendall, both correlations being significant at the .01 level. The fraternal twins' reactions correlated -.64 Pearson and -.56 Kendall, both correlations being significant at the .05 level of confidence. Only 11 pairs of each type of twins were used for the study. Investigations of similarities between reactions to DAF and stuttering in identical twins were suggested. Although this study cannot be construed as having found the causal factor in

DAF reaction, it does lead one to speculate about heredity as a factor to be further investigated.

Rawnsley and Harris (1954) added further evidence that stuttering and reaction to DAF are similar. Sound spectrograms of normal speakers under DAF conditions and of stutterers were compared. The spectrograms of repeated syllables showed the same coarticulation defects for both groups. Black (1951) has suggested that the additional characteristics of reaction to DAF, increase in intensity or pitch and slowing of rate, may only be secondary characteristics of the primary reaction which is thought to be a temporal and sequential disturbance as is stuttering. It is also mentioned by Van Riper (1971) that these secondary characteristics can be found in the reactions of young stutterers.

Neelley (1961) has taken the point of view that DAF reaction and stuttering behavior are dissimilar. A group of 23 stutterers was compared with a group of non-stutterers under normal feedback conditions and at .14 sec. DAF 75 db above threshold. Under each condition the task was to read a 100 word passage five times. Recordings were scored for omissions, additions, substitutions, and by a ratio of correct words to total reading time. Neelley's major conclusions were that: (a) With regard to additions, stutterers and non-stutterers under DAF conditions differ markedly, and (b) that the speech changes experienced by non-stutterers under DAF conditions are not like stuttering behavior.

Yates (1963) criticizes Neelley's work from two major standpoints. First, only one delay time and intensity level was used. The delay time selected was not optimal for producing reaction to DAF. Since

there is an interaction between intensity and delay time, any reaction reported for a single delay time and intensity may give very little evidence with respect to actual reaction to DAF. Secondly, DAF is a novel experience to most non-stutterers. Therefore, a certain amount of difference in their reaction to DAF as compared to stuttering behavior can be expected on that basis alone. Another variable must also be considered. Under DAF conditions, Chase, Sutton, and Rapin (1961), Goldiamond et al. (1966), and Soderberg (1969) report that stutterers increase in speed and show reduced stuttering. These findings are the basis for a behavior modification therapy program suggested for stutterers by Goldiamond (1966), Van Riper (1971) and Ryan (1974).

When one attempts to draw the above information together, a physiologically based model of stuttering and DAF reaction emerges. It seems quite likely that there is considerable variability in discrepancies between air conducted and bone-tissue-air sound among subjects, as pointed out by Stromsta (1956, 1959). The discrepancy being of a temporal nature may be due to a variety of physiological factors other than neurological processing problems. Stromsta (1959) reported in his review of the literature that the following differences in air conducted and bone-tissue-air conducted sound can be found: (a) Head resonance affecting amplitude is not a factor in air conduction. (b) The signal spectra are different for different conduction media. (c) Air conducted sound is transmitted by compressional wavefronts while bone-tissue-air conduction is transmitted by both shear and compressional wavefronts separately or in combination at the interface between conduction media. (d) Phase reversals over nodal lines in the skull can

be expected in bone conduction.

Such factors as individual geometry and density of the skull with special attention to the oral cavity and surrounding bone-tissue structure, as well as time of arrival of sound through air conduction at the cochleae, should be considered. If this is done, at least nine possible combinations of temporal reception disturbances can result from internal and/or external feedback discrepancies. It follows that, if one accepts these discrepancies as probable individual differences variables, some individuals while learning to speak have more adapting to do in order to use the feedback they receive than do others.

If it is hypothesized that stuttering and DAF reaction are manifestations of attempts to compensate for the discrepancies described above, one could further hypothesize the following: (a) Males may have different discrepancies to deal with than do females due to bone-tissue-air and air binaural conduction interaction, and may therefore show greater incidence of stuttering and lack of ability to adapt to DAF over short exposure times. (b) This may also account for the greater incidence of speech defects of all kinds in males than in females. (c) Twins may be expected to be more similar in stuttering and in DAF reaction than other siblings within the same family. The divergence of fraternal twins in DAF reaction reported above may be due to lack of control of sex as a contaminating factor.

Fear, anxiety, and outside stresses have been hypothesized as sources of stuttering by many theorists, such as Blanton (1936), Sheehan (1956), Travis (1956), Johnson (1967), and Bluemel (1957). Anxiety and stress reactions have also been noted in the DAF research.

Yates (1963) cited evidence by Doehring, and Doehring and Harbold, indicating that presentation of DAF is accompanied by changes in heart rate and GSR disturbances. Hanley et al. (1958) also showed that GSR disturbances accompany presentation of DAF. GSR disturbances and changes in heart rate have long been regarded as indications of anxiety. In a replication of a study by Korchin and Levine (1957) who used the TMAS to select subjects for a paired associates learning task, Rankin (1967) used DAF to induce anxiety in randomly chosen subjects with results paralleling those of Korchin and Levine. These results suggest that anxiety is present under DAF conditions, and that it may be a by-product of disruption of the usual speech-hearing feedback system.

One might further speculate that, if a young child has an unusual discrepancy in feedback to which he must adapt, parents are likely to become concerned when the child's speech maintains an unusual temporal quality past the normally expected early slurring and stuttering of beginning speech. It may be that at this time, anxiety is introduced through correction by adults and other children to the point of making adaptation more difficult for the child. This would further lead to hypothesizing that when such a child becomes an adult some adaptation has taken place. However, under anxiety producing conditions, when muscles tighten and contour of the oral cavity changes slightly (as well as other physiological changes take place), a slight change in feedback is perceived which may in such a case be enough to trigger the habit of stuttering rather than adapting. It could also be speculated that a vicious cycle may ensue in which

anxiety brings a slight shift in feedback, feedback increases anxiety, etc. Tolerance for feedback shifts may be quite variable from individual to individual, resulting in a variety of reactions--one of which may be stuttering. This seems to be in basic agreement with Sheehan's (1958) proposed double approach-avoidance-conflict.

Soderberg (1969) pointed out that other hypotheses and theoretical models presented to date have not been testable. It seems likely that the adaptation model expressed above is quite testable, since the reactions involved are of a physiological or a psychological nature, not only neurological. Work has begun toward the measurement of conduction discrepancies by Stromsta (1956). Both oscillographic and sound spectrographic analyses of stutterers and non-stutterers under normal and DAF conditions are now possible with long-term printed outputs.

Experiment 1

In order to study a possible developmental trend in DAF reaction, a stratified random sample was drawn from the Victoria, B.C., public schools. Five groups of 10 males and 10 females each, aged 5, 7, 9, 11, and 13 yrs., constituted the sample. Each subject recited a nursery rhyme under conditions of NAF and DAF. This task was chosen since many of the young subjects could not read, but all could recite the rhyme.

The speech of each subject was recorded under normal conditions and with delays of 113-, 226-, 306-, 403-, and 520-m/sec. Delay times were presented in random order.[2] The apparatus used to record speech and to produce delayed feedback was a Korting Constellation 88 with a moveable playback head. A Korting 285 dynamic microphone picked-up speech which was returned through a Sharpe 660 headset of 8 ohms nominal impedance. This apparatus was calibrated using a Tektronix 465 oscilloscope. The over-all band pass of the apparatus was 30 to 18K Hz. The feedback intensity was approximately 75 db above background noise, with slight variations produced by the subjects and limitations in the equipment.

Two methods of obtaining measurement of reaction to DAF were used. Differences in speaking time between NAF and DAF conditions were calculated to the nearest 1/100 sec. Differences calculated from the number of disfluencies (omissions, substitutions, repetitions, and additions) noted under NAF and DAF were also used. In order to establish reliability of the disfluency counts, a second observer's counts were correlated with those of the first. A Pearson product-moment correlation coefficient of .92 was obtained. Two three-way analyses of variance with repeated measures were calculated using the difference scores for time and disfluency.

Results and Discussion

In an analysis of variance, using difference scores calculated from speaking times under NAF and DAF conditions, significant differences were found in sensitivity of the age groups to delays (F = 53.9, df = 4/400, $p < .01$). Reactions to DAF differed from the various times used (F = 15.21, df = 4/360, $p < .01$). A significant interaction between age and delay time was also noted (F = 5.15, df = 16/360, $p < .01$). These results are summarized in Table 1 and in Figure 1.

Post hoc comparisons, using the Scheffé (1959) method, were calculated. Five-yr.-olds showed significantly greater reaction to 305-m/sec. delay than did 13-yr.-olds, and to 413- and 520-m/sec. than did 9-, 11-, and 13-yr. olds ($p < .01$). When delay times within age groups were compared, the 5-yr.-olds reacted with significantly greater speaking time at 413- and 520-m/sec. than at 113-m/sec. DAF ($p < .01$). No significant differences were found among delay times for 7-, 9-, and 13-yr.-olds ($p > .01$).

Sex differences in temporal reaction were statistically significant (F = 4.33, df = 1/400, $p < .05$). Post hoc comparisons showed that girls in the 7 yr.-old group reacted more strongly to 226-, 403-, and 520-m/sec. DAF than did boys. Within the 11-yr.-old group, girls reacted more strongly to the 413-m/sec. DAF than did boys. Thirteen-yr.-old girls reacted with longer speaking times when under 306- and 520-m/sec. delays than did boys. In all statistically significant comparisons, slowing of speech under conditions of DAF was greater for girls than for boys. No sex differences were found for the 5- and 9-yr.-old groups. Table 2 shows means and standard deviations for each group under all speaking conditions.

Using difference scores based on disfluencies under conditions of NAF and DAF, significant differences in reactions to delay times were found (F = 62.19, df = 4/360, p < .01) as shown in Table 3. A significant interaction between age and delay times was also noted (F = 5.19, df = 16/360, p < .01). Post hoc comparisons (Scheffé, 1959) showed that 5- and 7-yr.-olds were more disfluent at 413- and 520-m/sec. DAF than they were at 113-m/sec. delay (p < .01). Nine- and 11-yr.-olds were significantly more disfluent at 413-m/sec. than at 113-m/sec. (p < .01). At 520-m/sec. delay 5- and 7-yr.-olds made significantly more speech errors than did 9- and 13-yr.-olds (p < .01). No statistically significant sex differences in number of speech errors were found (p > .01).

These data indicate that the younger children were more affected by long delays than were the older children, supporting the findings of MacKay (1969) and Buxton (1969). It is thought that the variance in reaction to DAF may be due to age related differences in sensitivity to air-conducted feedback and/or to fluency in normal speech. When adults were told not to listen to their own speech by Goldiamond, et al. (1962) less effect of DAF was noted. It could be hypothesized that young children are more intent upon what they are trying to say than upon how their speech sounds--in effect not listening to their speech. Under these conditions, only large discrepancies in feedback may be noticed.

Lack of speech errors under NAF may also be a factor. Atkinson (1954) reported that those adults with high intelligibility in their speech under NAF conditions were less affected by DAF than those with low intelligibility under NAF. If these findings are applicable to children, young children could be expected to show more reaction to DAF than older ones as a function

of developmental factors related to intelligibility.

Further investigation of these factors in relation to reactions to DAF seems warranted. Control of age and sex factors in the present research is also indicated.

Experiment 2

The hypothesis that stutterers differ from non-stutterers in sound conduction rate from the larynx to the mastoid process (Timmons and Boudreau, 1972) was tested. Ten stutterers and 10 non-stutterers matched by age and sex constituted the sample. Both air and bone-tissue-air conduction were measured for each subject.

Square waves were driven from a Tektronix FG 501 function generator at a level of 93 db to a Sennheiser transducer placed against the skin over the larynx. A Bruel and Kjaer 4152 directional, pressure microphone was placed against the mastoid process. The microphone was attached to a Tektronix 465 oscilloscope. When the microphone was solidly against the mastoid process, bone-tissue-air conduction could be measured. By slightly lifting the microphone air conduction could be measured.

Conduction rates were recorded in microseconds for the four channels (external and internal for leading and following ears). A two-way analysis of variance with repeated measures was calculated, using the conduction rate data. In addition, binaural difference scores were calculated by adding the internal differences to the external differences in conduction for each subject. A *t*-test was calculated to test for differences between stutterers and non-stutterers on the composite, binaural, discrepancy scores.

Results and Discussion

In a two-way analysis of variance, using conduction rates for four channels, no significant differences were found between stutterers and non-stutterers ($p > .05$). Significant differences were found among

the conduction channel rates (F = 21.22, df = 3/54, p < .001). No significant interaction between stutters/non-stutterers and conduction channels was noted (p > .05). These results are summarized in Table 4.

Post hoc comparisons, using the Scheffé (1959) method, were calculated for conduction channels. Binaural differences in external conduction channels were found to be significant for both groups (p < .05). Binaural conduction differences in the internal channels were found to be significant for the stutterers (p < .01).

When the groups were compared through the use of a t-test on composite, binaural, discrepancy scores, significant differences were found (t = 3.78, df = 18, p < .01). The data used in this comparison can be found in Table 5.

These data indicate that although stutterers and non-stutterers do not differ in comparison on any pair of conduction channels, the over-all conduction rates taken binaurally are significantly different. These comparisons are based on the first of three waves reaching the microphone from internally conducted sound, and on a single wave recorded from air conduction. Stromsta (1962) indicated the relative rates of various conduction media, the most rapid being bone. It seems likely that the internal conduction measured was predominantly bone conduction.

Further exploration of discrepancies in the binaural conduction of sound in relation to speech disfluencies seems warranted. Particular emphases on the interface between conduction media and on more reliable, computer-controlled measurement could be of interest in the exploration of the possible causes of stuttering hypothesized by Timmons and Boudreau (1972).

Experiment 3

Two groups of 25 subjects each constituted the sample for the study of physiological indicators of stress in relation to NAF and DAF conditions. The experimental group consisted of children identified as stutterers by the speech therapists of school districts in Victoria, B.C., and Tacoma, Washington. Control subjects were non-stutterers matched with the experimental group by age, sex and speaking tasks. The matched pairs ranged in age from 5 to 16 yrs.

The speech of each subject was recorded under conditions of NAF and 113-, 226-, 306-, 413-, and 520-m/sec. The DAF conditions were presented in random order. The apparatus used to record and produce DAF was a Korting Constellation 88 with a moveable playback head. A Korting 285 dynamic microphone picked up speech which was returned through a Sharpe 660 headset of 8 ohms nominal impedance. The apparatus was calibrated with a Tektronix 465 oscilloscope. The over-all band pass of the apparatus was 30 to 18K Hz. The feedback intensity was approximately 75 db above background noise with slight variation due to intensity changes produced by the subjects and limitations in the equipment.

The subjects read materials from the S.R.A. Elementary Reading Laboratory (Parker, 1958), or recited nursery rhymes. Independent reading level was used for selection of materials. Non-readers recited nursery rhymes.

Pulse rate was measured through a simple wrist count, using a digital timer. A repeated measures two-way analysis of variance was calculated to determine if differences in pulse rate between the groups and among the feedback conditions could be demonstrated.

Since heart rate and Galvanic Skin Response (GSR) have long been regarded as indicators of stress, they were studied in relation to feedback conditions presented to stutterers and non-stutterers. Pulse rate was measured under each of the feedback conditions through a simple wrist count, using a digital timer. GSR was measured, using a Tektronix DM 501 digital multimeter in the ohm-meter mode. Each subject's lowest GSR reading was recorded for each of the six feedback conditions. Two-way analyses of variance with repeated measures were calculated.

Results and Discussion

In the repeated measures two-way analysis of variance of pulse rates, no significant differences were found between stutterers and non-stutterers under NAF and DAF conditions ($F = 1.33$, $df = 1/48$, $p > .01$). Pulse rates were significant for both groups under the various feedback conditions ($F = 3.17$, $df = 5/240$, $p < .01$). (These results are summarized in Table 6.) Post hoc comparisons, using the Scheffé method (1959), were significant between NAF conditions and 413- and 520-m/sec. DAF ($p < .01$). No significant interaction was found ($p > .05$).

A repeated measures two-way analysis of variance of GSR readings for the groups under six feedback conditions (see Table 7) showed no significant differences between stutterers and non-stutterers ($F = 0.49$, $df = 1/48$, $p > .01$). No significant differences among feedback conditions were found ($F = .79$, $df = 5/240$, $p > .01$). No significant interaction was found.

The results confirmed the observations of Doehring (1956) and Doehring and Harbold (1957) that under conditions of DAF heart rate increases over that of NAF. No support for the notion that GSR also varies from NAF to DAF conditions could be found. This may be due to differences in measurement techniques used.

The results of this experiment indicated that stutterers and non-stutterers do not differ in GSR or in pulse rate under NAF and the five DAF conditions used. Although pulse rate varied with the shift from NAF to DAF presentations, indicating either stress or an attention orienting response related to the novelty of the experience, this reaction did not differ between the groups. When anxiety is defined in terms of GSR and pulse rate changes, it appears that stutterers are neither more nor less anxious than non-stutterers under NAF and DAF conditions used. This may be related to the task difficulty factors, since simple tasks were used and DAF reaction seems to be intensified with the use of difficult materials (Spilka, 1954; Winchester, Gibbons, & Haggarty, 1954). Further investigation seems warranted, since many theorists attribute stuttering behavior to stress factors.

Experiment 4

To further pursue the possible relationship between anxiety and reaction to DAF, the Taylor Manifest Anxiety Scale (TMAS) was given to 32 University of Victoria undergraduate students. The TMAS was chosen due to the parallel drawn between scores on it and DAF reactions (Rankin, 1967). TMAS scores were correlated with reactions to 226 msec. DAF conditions produced by the same apparatus used in Experiment 3. DAF reaction was measured by differences in speaking rate under NAF and DAF conditions (Black, 1951). The subjects read a 300 word difficult, graduate level, prose passage which was chosen in an attempt to maximize DAF effect.

Results and Discussion

Both a Pearson product-moment ($r = .21$) and a Kendall's tau ($\tau = .01$) correlation were calculated. Neither correlation was found to be significantly different from zero ($p > .05$).

The TMAS is known to be weak in discrimination in the mid-ranges. It is probably an inappropriate measure of anxiety to be used here. More reliable speech anxiety scales are now available and would probably have more meaning in relation to DAF reaction.

Experiment 5

The purpose of this study was to further define similarities and differences between stutterers and non-stutterers under NAF and DAF conditions through the use of disfluency, time, and spectroscopic information. Thirty-eight stutterers and 38 non-stutterers matched by age, sex, and speaking task constituted the sample (Twenty-five of these pairs were used in Experiment 3 also). The experimental group consisted of subjects identified as stutterers by speech therapists from school districts in Victoria, B.C. and Tacoma, Washington and from the University of British Columbia. No attempt to separate the stutterers by severity of speech disfluency or type was made. The matched pairs ranged in age from 5 to 30 years.

The speech of each subject was recorded under conditions of NAF, and 113-, 226-, 306-, 413-, and 520-msec. The DAF conditions were presented in random order for each subject. The apparatus used to record and produce DAF was a Korting Constellation 88 with a moveable playback head. A Korting 285 dynamic microphone picked up speech which was returned through a Sharpe 660 headset of 8 ohms nominal impedance. The apparatus was calibrated with a Tektronix 465 oscilloscope. The over-all band pass of the apparatus was 30 to 18K Hz. The feedback intensity was approximately 75 db above background noise with slight variations due to intensity changes produced by the subjects and limitations in the equipment.

The subjects either read materials from the S.R.A. Elementary Reading Laboratory (Parker, 1958) or recited nursery rhymes. Materials were selected based upon ease of reading or recitation. If both members

of a pair could read or recite the passage given with 5% or fewer errors, the task was considered appropriate.

All of the speech samples were then dubbed from the Korting Constellation 88 to an Ampex 351, full-track, audio-tape recorder at 15 inches per second. Disfluency counts based on the number of omissions, substitutions, additions, and repetitions in each sample were taken by two observers. A Pearson product-moment coefficient of .90 was obtained between the two observations, indicating a high degree of reliability. One set of the data was then used to calculate a two-way analysis of variance.

The data were then fed from the Ampex 351 recorder to an 1856 Honeywell Fiber Optic Cathode Ray Tube Recorder with capabilities of X, Y, Y', and Z axis recording, having a DC to 10 MHz frequency response. This recorder (oscillograph) was driven by a Honeywell 51B Real Time Analyzer with contour display modification, having simulated 3D display which could be viewed on a Tekronix 611 storage oscilloscope. The output of the Real Time Analyzer had computer interface with an Intel 8080 microcomputer programmed to calculate areas in from 1 to 8 levels of the contour oscillograms produced on the 1856 Honeywell oscillograph. The levels between contours were adjustable to accommodate from 3 to 20 db per step.

Time was measured on the X axis, frequency on the Y', and intensity of vocal production on the Z. Speaking times were compared for the groups, using a two-way analysis of variance with repeated measures. Total area under the contours for each speech sample was computed. This represented the interaction of time, frequency, and intensity for each subject under each speaking condition. These scores were also entered into a two-way analysis of variance. Visual comparisons of the speech samples of both groups were also done.

Results and Discussion

In a two-way analysis of variance with repeated measures, summarized in Table 8, disfluency counts were shown to be significantly different between stutterers and non-stutterers ($F = 4.55$, $df = 1/74$, $p < .05$). Delay time used was also shown to be significant ($F = 12.42$, $df = 5/370$, $p < .001$). No significant interaction between groups and delay times was found ($p > .05$).

Post hoc comparisions, using the Scheffé (1959) method, indicated that stutterers differ significantly from non-stutterers in total disfluency counts under NAF, and 413-520-msec. DAF conditions. Stutterers showed significantly greater reaction to DAF, as indicated by higher disfluency counts, at 520-msec. DAF than under NAF conditions. There was also statistically significant differences between stutterers reaction to 226-msec. and 413-msec. and between 224-msec. and 520-msec. DAF. Stutterers appear to be more affected by long delays in auditory feedback than in short ones. Non-stutterers' reactions were significant when NAF was compared with 306-, 413-, and 520-msec. DAF conditions. All comparisons are reported at the .05 level of confidence.

It is interesting to note that no differences between stutterers and non-stutterers could be found at 113-, 226-, and 306-msec. DAF. This was due to increases in disfluencies in the non-stutterers while the stutterers maintained a fairly constant level of disfluency. No indication that stuttering is decreased through the use of DAF was found, although for some individuals this appeared to be the case; for others it obviously was not. Spectroscopic data are still to be analyzed.

Conclusions and Implications for Future Research

This section of the report will be divided into two subsections. The first will deal with possible improvements in speech therapy, the second with possible causal factors in stuttering.

Speech Therapy

Although the findings of these studies do not support the contention that stuttering is reduced under DAF conditions (Chase, Sutton, and Rapin, 1961; Goldiamond, 1966; Soderberg, 1969), a reduction in stuttering may have occurred. If decreased stuttering is related to the DAF conditions used with adults, one could speculate that delay times used are of importance in children's reactions. It has been shown that age and sex are variables related to the reactions of non-stuttering children under various DAF conditions. Since both age and sex were allowed to vary within the stuttering and non-stuttering groups in Experiments 3, 4, and 5, no reduction in stuttering as a result of specific age and sex related delay times could be noted.

If DAF is to be used efficiently in therapy for stuttering children, age and sex as related to delay times used should be studied for this group. The amount of time spent in speech therapy could conceivably be reduced, if the proper use of DAF equipment could be made through selection of appropriate delay times based on a detailed study of the characteristics of stutterers related to their reactions. Two important characteristics may be age and sex.

Contour spectrograms may also aid in diagnosis of speech difficulties as well as in following the course of therapy. It is conceivable that with the use of computer matching procedures contour spectrograms for

individuals could be compared with a large bank of spectrograms for previously diagnosed speech difficulties. The best fit of the contours could be made by the computer, yielding rapid diagnostic information.

As therapy progressed, speech changes could be monitored in a more sophisticated manner than is now used. Contour spectrograms could be studied for the specific changes which occurred during therapy. Progress could then be measured with less dependence upon the perceptions of the stutterer and his therapist. It seems that reliability of measurement could greatly be increased in this manner.

Causal Factors Related to Stuttering

The conduction rates for internal and external auditory channels were studied to determine whether or not a physiological difference between stutterers and non-stutterers could be shown. Although an analysis of variance of the conduction rates showed no differences, a composite score for discrepancies within each individual was calculated to determine whether the over-all conduction pattern differed between the groups. The result of the over-all conduction comparison was statistically significant. No information about the specific sources of the discrepancies was obtained. It seems likely that the interfaces among the media in internal conduction are an important source of conduction discrepancies between auditory channels. It also seems likely that the interfaces would change markedly in conduction of sound under stress conditions. In the present research, each subject was a passive participant. When a subject produces the sounds himself, and when stress is added, many changes in conduction may occur due to tension in the muscle through which the sound must pass. Any changes in muscle tension results in changes in interface with bone, altering the conduction rate and over-all pattern of conduction.

It seems likely that future research should include active subject participation under a variety of speaking conditions, and computer-assisted monitoring of changes in internal conduction. A measure of muscle tension during speech, coupled with conduction rate data, would be a beginning.

No differences in pulse rate or GSR were noted between the stutterers and the non-stutterers. This seems contrary to most theoretical and observational data available about stutterers, if these measures are taken as indicators of stress or anxiety in speaking situations. It could be speculated, however, that stutterers may not differ from non-stutterers in level of physiological stress while speaking, but may differ in focus of that stress. The focus of the stutterer's stress reactions to novel speaking conditions may be the muscles involved in conduction of sound from the larynx to the mastoid. This could be studied as a part of further conduction rate research.

TABLE 1

ANALYSIS OF VARIANCE OF SPEAKING RATES FOR MALES AND FEMALES

IN FIVE AGE GROUPS UNDER FIVE DAF CONDITIONS

Source	SS	df	MS	F
Between Subjects	4574856.00	99		
Age Groups	3139840.00	4	784953.50	53.90**
Sex	63123.00	1	63123.00	4.33*
Age X Sex	61316.00	4	15329.00	1.05
Subjects Within Groups	1310603.00	90	14562.23	
Within Subjects	1026176.00	400		
DAF Conditions	119278.00	4	29819.50	15.21**
Age X DAF	161420.00	16	10088.75	5.15**
Sex X DAF	6012.00	4	1503.00	0.77
Age X Sex X DAF	33727.00	16	2107.94	1.08
DAF X Subjects Within Groups	705742.00	360	1960.39	

*p < .05

**p < .001

TABLE 2

MEANS AND STANDARD DEVIATIONS OF SPEAKING RATES IN SECONDS FOR FIVE AGE GROUPS UNDER SIX FEEDBACK CONDITIONS

Delay Time in msec.		000	113	226	306	413	520
13 year olds	$\bar{X}$	6.76	12.38	12.70	12.97	13.85	11.87
	s_X	1.19	6.74	4.84	6.87	7.02	7.57
Males	$\bar{X}$	6.76	11.04	12.16	10.52	13.21	9.42
	s_X	1.41	3.87	4.42	2.17	4.45	4.18
Females	$\bar{X}$	6.76	13.71	13.24	15.40	14.48	14.31
	s_X	1.00	8.77	5.41	9.13	9.12	9.50
11 year olds	$\bar{X}$	7.37	14.14	13.69	15.77	15.20	14.41
	s_X	1.82	4.35	3.42	6.40	6.10	5.81
Males	$\bar{X}$	7.65	12.90	13.07	14.17	12.89	13.18
	s_X	2.06	4.11	4.02	5.95	4.37	5.76
Females	$\bar{X}$	7.11	14.27	14.30	17.37	17.51	15.63
	s_X	1.62	3.33	2.78	6.73	6.91	5.90
9 year olds	$\bar{X}$	7.79	14.72	17.29	16.16	15.99	14.90
	s_X	1.80	4.45	4.48	5.84	5.80	6.30
Males	$\bar{X}$	8.04	14.36	17.65	16.47	16.19	16.39
	s_X	1.86	4.25	4.24	5.27	6.25	6.78

Females	$\bar{x}$	7.53	15.07	16.93	15.85	15.78	13.41
	s_x	1.79	4.85	4.92	6.64	5.65	5.74
7 year olds							
	$\bar{x}$	9.95	20.90	24.63	27.64	27.98	28.06
	s_x	2.73	3.76	6.98	6.46	7.92	8.48
Males	$\bar{x}$	10.41	19.81	22.16	26.42	23.34	25.78
	s_x	3.31	3.23	4.04	6.63	4.46	5.78
Females	$\bar{x}$	9.49	21.99	27.08	28.85	32.62	30.34
	s_x	2.08	4.10	8.55	6.39	8.04	10.33
5 year olds							
	$\bar{x}$	8.91	28.47	34.49	36.96	38.74	42.39
	s_x	1.82	6.45	8.67	11.78	8.63	10.44
Males	$\bar{x}$	9.52	30.63	33.90	38.17	39.09	42.30
	s_x	2.35	7.64	8.24	10.23	9.75	6.69
Females	$\bar{x}$	8.29	26.31	35.07	35.74	38.39	40.67
	s_x	0.81	4.36	9.49	13.61	7.86	11.09

TABLE 3

ANALYSIS OF VARIANCE OF DISFLUENCIES FOR MALES AND FEMALES IN FIVE AGE GROUPS UNDER FIVE DAF CONDITIONS

Source	SS	df	MS	F
Between Subjects	2141.12	99		
Age Groups	69.45	4	17.36	0.81
Sex	16.93	1	16.93	0.79
Age X Sex	132.50	4	33.12	1.55
Subjects Within Groups	1922.32	90	21.36	
Within Subjects	4834.60	400		
DAF Conditions	1690.77	4	422.69	62.19*
Age X DAF	564.67	16	35.29	5.19*
Sex X DAF	29.73	4	7.43	1.09
Age X Sex X DAF	101.54	16	6.35	0.93
DAF X Subjects Within Groups	2446.88	360	6.80	

* $p < .001$

TABLE 4

ANALYSIS OF VARIANCE OF CONDUCTION RATES

FOR STUTTERERS AND NON-STUTTERERS

Source	SS	df	MS	F
Between Subjects	3089.50	19		
Fluency Groups	72.11	1	72.11	0.43
Subjects Within Groups	3017.31	18	167.63	
Within Subjects	862.50	60		
Conduction Channel	440.00	3	146.67	21.22
Fluency X Channel	49.30	3	16.43	2.38
Channel X Subjects Within Groups	373.19	54	6.91	

TABLE 6

ANALYSIS OF VARIANCE OF PULSE RATE FOR STUTTERERS AND NON-STUTTERERS UNDER SIX FEEDBACK CONDITIONS

Source	SS	df	MS	F
Between Subjects	25628.00	49		
Fluency Groups	690.63	1	690.63	1.33
Subjects Within Groups	24938.00	48	519.54	
Within Subjects	8037.00	250		
Feedback Conditions	489.06	5	97.81	3.17*
Fluency x Feedback	154.69	5	30.94	1.00
Feedback x Subjects Within Groups	7397.00	240	30.82	

*$p < .01$

TABLE 7

ANALYSIS OF VARIANCE OF G.S.R. FOR STUTTERERS AND NON-STUTTERERS UNDER SIX FEEDBACK CONDITIONS

Source	SS	df	MS	F
Between Subjects	1076473.85	49		
Fluency Groups	11004.89	1	11004.89	0.50
Subjects Within Groups	1065468.96	48	22197.27	
Within Subjects	264615.00	250		
Feedback Conditions	4227.54	5	845.51	0.79
Fluency x Feedback	3998.93	5	799.79	0.75
Feedback x Subjects Within Groups	256390.19	240	1068.30	

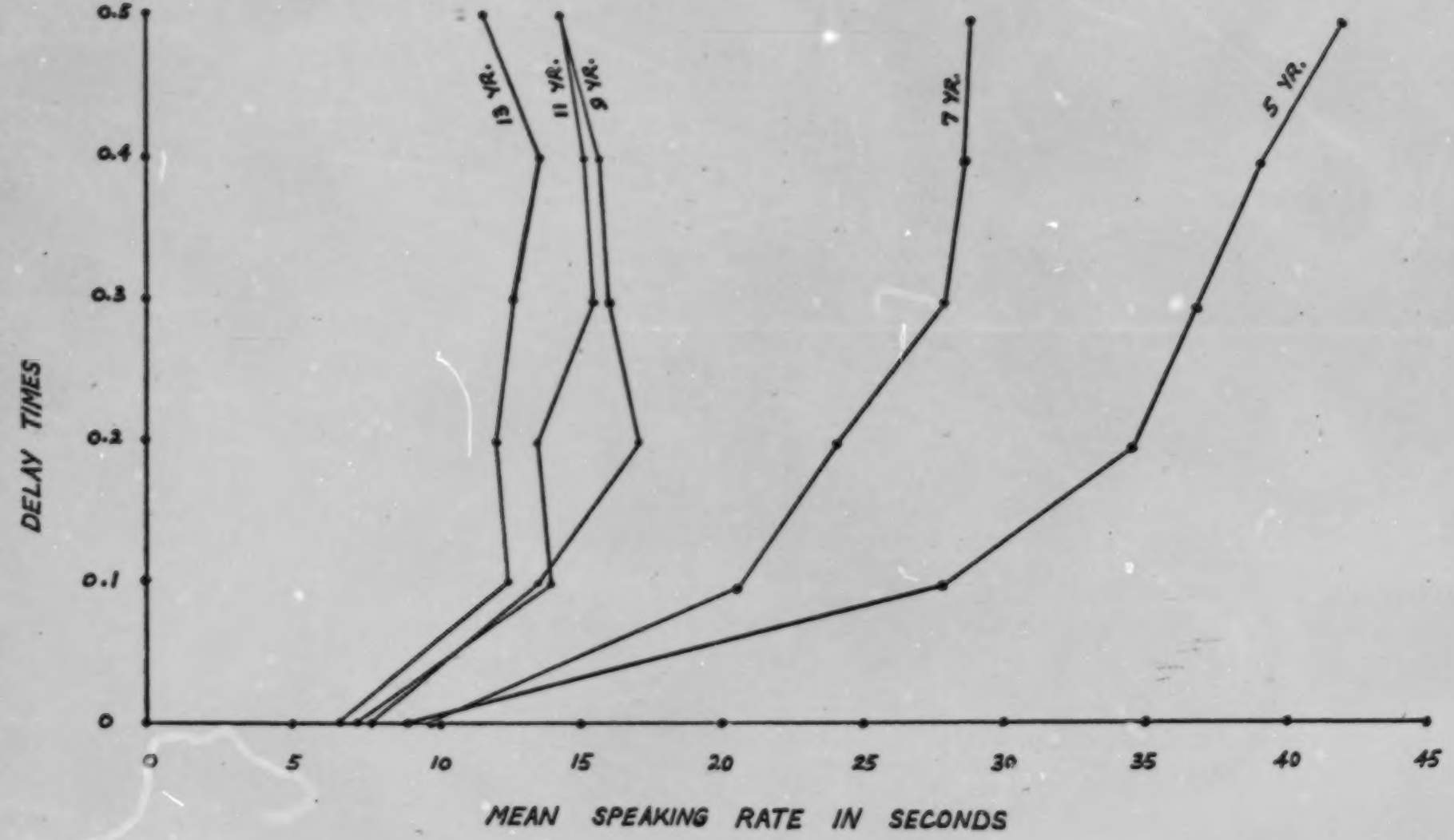
0.5
0.4
0.3
0.2
0.1
0
DELAY TIMES
13 YR.
11 YR.
9 YR.
7 YR.
5 YR.
0
5
10
15
20
25
30
35
40
45
MEAN SPEAKING RATE IN SECONDS

FIG. 1

FOOTNOTES

[1] Parts of this report have been published in the Journal of Speech and Hearing Disorders and in Perceptual and Motor Skills.

[2] Credit is due to Miss Ann Tamboline for her assistance in gathering data for Experiments 1 and 3.

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